dihydroxyphenols, but not mono-phenols, is more probably due to the catalysing effect of organic colloidal material than to a true enzyme as stated by Gortner. The extreme resistance to high temperatures shown by these extracts excludes the presence of an enzyme as generally understood.

9. Variations in coat-colour are due probably to a quantitative rather than to a qualitative difference in the pigment present, for the pigments isolated from black, chocolate, and yellow rabbits show very little difference either in the depth of their colour or in their chemical behaviour.

10. Blue and the other dilute coat-colours are not caused by a lack of pigment in the medulla, but by the absence of granules in the cortex, which, being present in the intense colours, absorb the light which in the dilute colours is reflected from the vacuoles.

In conclusion, the writer of this paper wishes to acknowledge his indebtedness to Mr. S. W. Cole for his invaluable suggestions and help throughout the course of the experiments, and to Prof. F. G. Hopkins for his kindness in revising the paper.

The Transmission of Infra-red Rays by the Media of the Eye and the Transmission of Radiant Energy by Crookes and other Glasses.

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(Report of Experiments carried out for the Glassworkers' Cataract Committee of the Royal Society.)

(From the Physiological Laboratory, Cambridge.)

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Our experiments were designed to obtain evidence on the following points:—

(1) In what amount do the infra-red radiations of different wave-length gain access to the deeper structures of the eye, the lens being particularly considered?

(2) What percentage of these radiations is absorbed in transmission through the lens?

The apparatus is shown in fig. 1; it consisted of a standard constant deviation Hilger spectrometer, which was modified in the following manner.

The eyepiece being removed from the telescope was replaced by an adjustable vertical slit, immediately behind which was mounted a delicate thermopile of 10 bismuth-silver elements.* The terminals of the thermopile were connected directly to a Paschen galvanometer† by the deflection of which the energy falling on the thermopile could be measured. The whole telescope was insulated from radiant and convected heat by a

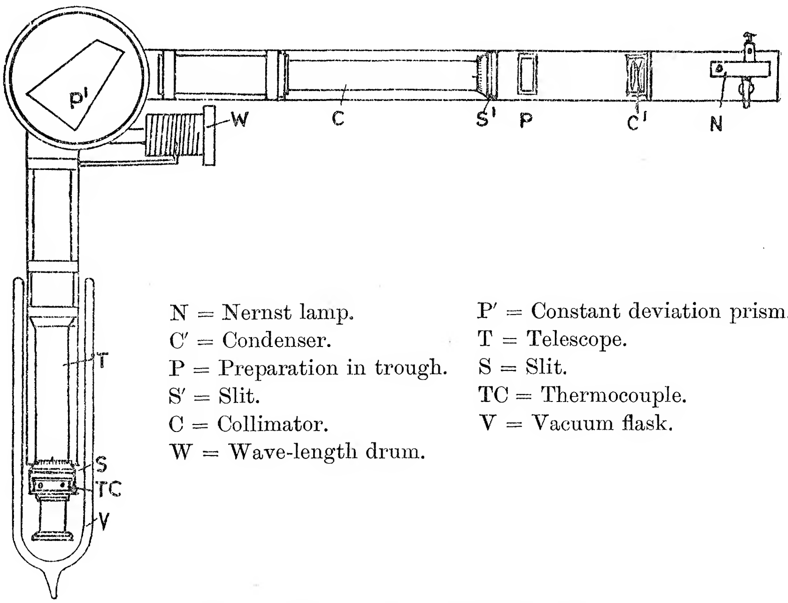

Fig. 1.—Plan of Infra-red Spectrometer.

silvered vacuum flask, the mouth of which was closed by dry cotton wool. The prism was of special dense flint, and the prism table was calibrated in wave-lengths throughout the visible and infra-red regions to λ 20,000. The collimator slit had specially curved jaws to compensate for the difference in refraction suffered by an oblique ray compared with one falling normally on to the prism surface. The condenser system was mounted on a long arm which extended beyond and in a line with the collimator. The light source was a single vertical Nernst filament, taking 100 watts, approximately. The positions and focal lengths of the lenses forming the condenser system were carefully studied, the principle employed in the construction being one that had been found by one of us to be very valuable when applied to the microscope.‡ The lens system consisted of two chief components. The first component consisted of two separate lenses which collected the rays diverging

* 'Trans. Optical Soc.,' vol. 13, p. 179.

† A Broca galvanometer was used for the earlier experiments.

‡ 'Roy. Micro. Soc.,' 1913, p. 365.

from the light source and forming a magnified inverted aplanatic image on the slit of the collimator. The function of the second component was to act as field lens; it formed a magnified inverted image of a plane situated between the two lenses of the first component on to the plane of the collimator lens. The aperture of the condenser system was purposely made considerably greater than was actually required to fill completely the aperture of the collimator. The object of this system may be indicated as follows. If a piece of plane parallel glass or a thin trough with plane sides containing fluid be interposed between a lens and the plane at which it is forming an image, but little disturbance will occur. If, however, the sides of the glass be not parallel or if there is any lens action, then considerable alteration will occur not only in the position of the image but also in its definition. As will be explained in dealing with the measurements on the lens of the eye, no matter how carefully the refracting power of the lens is neutralised, there will always be some residual refraction, particularly when waves differing from one another greatly in length are to be measured. Now one property of the condenser system employed is that it is to a considerable extent unaffected by small changes in focus brought about by weak positive or negative lenses placed between its components.

The object of our earlier experiments was to ascertain the best way of dealing with the different eye media. We found that the aqueous and vitreous humour when placed in a small trough with parallel sides gave a clear sharp image when a distant light source was looked at through the trough. With the lens and cornea this, of course, would not be the case. We tried two ways of dealing with the former. The first was to take several lenses, dry them superficially, and then squeeze them into the small trough, removing air bubbles with a small glass rod. This method was quite unsuccessful; the difference in refractive index of the different zones of the eyes was found to give a series of confused images of a distant light source. The second way was to immerse the uninjured lens in some fluid of suitable refractive index that would neutralise the convergence exerted by the lens on a parallel beam of light passing through it.

There are several groups of substances that could be used for this purpose; we had, however, to select one which, besides having the right refractive index, also showed no marked selective absorption in the infra-red region. After examining a number of oils and hydrocarbons of the paraffin series we found in carbon tetrachloride the body most suitable for our purpose. We found it to have no absorption bands over the range required, a result which confirmed Abney's* data for the same substance. Further, its refractive

* Abney and Festing, 'Roy. Soc. Proc.,' vol. 38, p 77 (1884–5).

index was nearly the same as that of the lens, the values being 1·46072 and 1·42 respectively.

It does not precipitate the proteids of the lens and yet has marked antiseptic properties. We found that if a cover was put over the trough containing the lens to prevent the evaporation of the carbon tetrachloride, the preparation remained clear and bright and could have been used on several successive days had this been necessary. We used in our experiments the eyes of the ox, for their large size was a distinct advantage for our purpose. The lens and vitreous were generally removed together by making a wide lateral incision circumferential to the globe and then carefully expressing the contents. We found this method superior to our original technique, in which we removed the lens by the ordinary operation for extraction of cataract. The lens was then carefully separated from the vitreous and was introduced into the trough by gently squeezing it between two plates of glass which were held parallel with the sides of the trough. The carbon tetrachloride was then poured in and the lens prevented from floating up to the surface by a small piece of thick copper wire which was bent so as to fit the upper edge of the lens, the ends of the wire being fastened with plasticine to the top of the trough. The remaining refractivity of the preparation was now neutralised by a concave lens of suitable power fixed outside the trough. On the other side was fastened a tinfoil diaphragm, the aperture in this being freshly cut for each preparation, only so much of the lens being used as could be simultaneously neutralised; as a rule the aperture measured between 5 and 7 mm.

Table I.—Table showing Comparative Values of Infra-red Rays of Different Length transmitted by the Lens and by an Equal Thickness of Water.

λ.	Water.	Lens.	Ratio.
7,000	11	8	0·73
7,500	18	14	0·78
8,000	26·5	21·5	0·81
8,500	35	31·5	0·90
9,000	44	41	0·93
9,500	42·5	39	0·92
10,000	51	52	1·02
10,500	71·5	72	1·00
11,000	78·5	77	0·98
11,500	48·5	46	0·95
12,000	41	45	1·10
12,500	50·5	56·5	1·12
12,750	51·5	58	1·13
13,000	44	55	1·25
13,500	14	30	2·1
14,000	2	4	2

This Table is shown plotted in fig. 2.

Preliminary observations with lens preparations made in this way showed us that the absorption bands in the infra-red corresponded very closely in position to those of water. On closer comparison, however, we found that there was in addition in the lens preparation what appeared to be a more general absorption which gradually increased in amount as one passed toward the visible spectrum. Fig. 2 is typical of the results we obtained with several different lens preparations. Several explanations occurred to us to

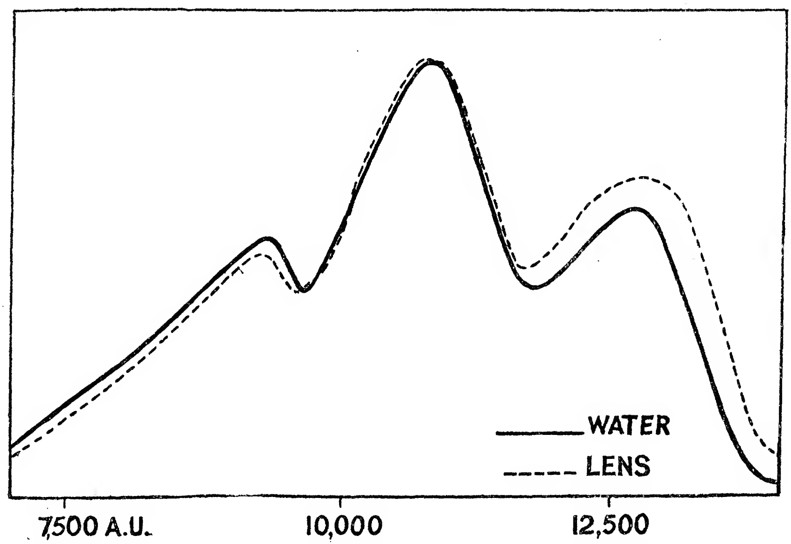

Fig. 2.—Comparison of Amount of Infra-red Energy of Different Wave-length transmitted by Lens and by an Equal Thickness of Water.

Swing of galvanometer vertical. Wave-length horizontal.

account for these results. We first supposed that there was some substance present in the lens with a very diffuse absorption band. This, however, would not fit in with the fact that the absorption band, extending as it did to 7500, would be seen in the visible spectrum and would therefore cause the lens to appear greenish in colour. Our second theory was that in spite of the special condenser system, described above, we were getting the effects of the difference in dispersion between the visible and infra-red rays, so that, while the infra-red rays in the case of the figures mentioned above were properly focussing on to the slit, some of the visible rays crossed too early and were lost. This explanation too had to be abandoned for several reasons. In no case were we able by changing the focus to get the reverse effect, *i.e.*, the visible rays giving full values and corresponding to water, and the infra-red rays giving values which fell more and more away from the water curve. A considerable change

in focus of the condenser did not alter the values at any one point. The values we obtained at different times with different lens preparations agreed with one another. At last the true cause occurred to us, namely, that the lens only contains perhaps 90 per cent. water and we were therefore comparing two unequal thicknesses of water. In making further series we therefore reduced the thickness of water from 10·15 mm. to 8·7 mm. by a thin glass plate, the same being done in examining the vitreous and aqueous humours.

Table II.—Comparative Values of Amount of Infra-red Energy of Different Wave-length transmitted by the Lens and Aqueous and Vitreous Humours and by an Equivalent Thickness of Water.

Wave-length in Å.U.	Water.	Deflection of galvanometer.		
		Aqueous.	Vitreous.	Lens.
		mm.	mm.	mm.
13,500	14	13	15	22·8
13,000	44	40	50	53·5
12,500	50·5	48	56	54·1
12,000	41	38·5	44	44
11,500	48·5	45	53	49·5
11,000	78·5	75	89·5	75
10,500	71·5	68·5	83	71
10,000	51	50	59	49
9,500	42·5	38·5	46	42·5
9,000	44	40	47	38·5
8,500	35	31·5	37	31
8,000	26·5	24	30	25
7,500	18	16·5	21·5	15·5

This Table is shown plotted in figs. 3, 4 and 5.

The correspondence between the absorption curves obtained for the different eye media and for water was now nearly complete, the values given in Table II and shown plotted in figs. 3, 4 and 5 may be given as examples. It seems clear therefore that no considerable difference exists between the absorption bands of the eye media and those of water. This conclusion which we had already reached has been confirmed by finding a paper by Aschkinass,* who investigated the permeability of the eye media to red and infra-red rays.

Aschkinass first made a careful investigation of the absorption bands of water, in thicknesses from 10 μ up to 1 metre; he found bands at 0·77 μ, 1·0 μ, 1·25 μ, 1·5 μ, and 1·94 μ. The method used was that of the bolometer, in which one scale-division on the galvanometer represented 30×10^{-6} °C. Our method must be some six or seven times as sensitive as this, and the

* 'Wied. Ann.,' vol. 55, p. 401 (1895).

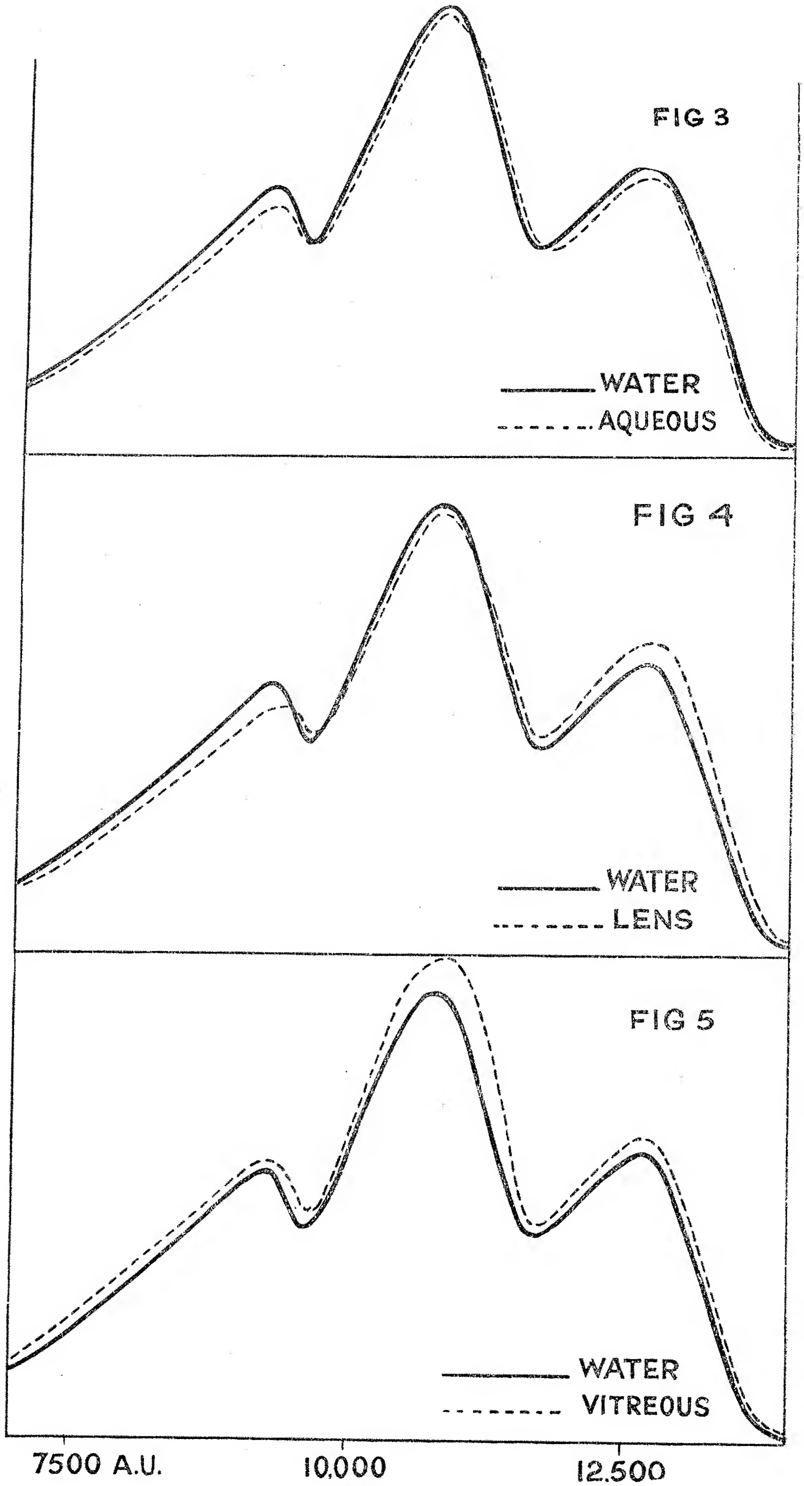
FIG 3
WATER
AQUEOUS
FIG 4
WATER
LENS
FIG 5
WATER
VITREOUS
7500 A.U.
10,000
12,500

dispersion and "over-lap" are probably better. He then investigated in order the absorption by the cornea, the aqueous, the lens, and the vitreous of the bullock's eye. In the cornea, when pressed flat, there is almost invariably some degree of cloudiness: this we also have observed, and the cloudiness probably leads to some general absorption throughout the whole range of wave-lengths. Aschkinass found that the general absorption produced by this cloudiness is greater the shorter the wave-length, and diminishes (as one might expect) considerably for the longer waves. There is no reason to suppose that in the normal eye this phenomenon causes any absorption at all (in the condition of glaucoma, however, it probably does): and Aschkinass, finding absorption bands at $1{\cdot}00\,\mu$, $1{\cdot}25\,\mu$, and $1{\cdot}50\,\mu$, comes to the conclusion that "the absorption follows the same course as for water." The same result he found, quite definitely and clearly, for the aqueous and the vitreous. With regard to the lens, the proof of the quantitative equality of the absorption to that of water was more difficult, as we have pointed out above. Aschkinass did not, as we have done, immerse the lens in some non-absorbing fluid (CCl_4) of approximately the same refractive index: he trusted simply to pressing it between two glass plates. He still found, however, that by virtue of its inhomogeneity it continued to act as a lens, and in order to deal with the absolute value of the absorption he had to apply a correction. Qualitatively, identically the same bands were seen as in the case of water, and quantitatively he came to the same conclusion as ourselves, viz., that the absorption of the lens is in no considerable way different from that of water.

The absorption of radiant heat by water has been known for some time. Julius investigated the absorption of both water and NaCl solution in small thicknesses. Abney,* using both photometric and thermometric methods, investigated very completely the absorption of water up to layers 2 feet thick. He found that water between the sodium lines and $2{\cdot}4\,\mu$ had absorption bands with the following maxima 0·580, 0 670, 0·780, 0·860, 0·970, 1·20, 1·45, 1·90, and 2·50 approximately, the first four bands being shallow except for thick layers; the last five bands being of increasing depth. Paschen† carried out a more complete investigation of the far infra-red absorption up to $10\,\mu$; he found that thin layers of water even take up a considerable portion of the incident radiation of wave-length greater than $2{\cdot}3\,\mu$. Thus a layer 0·03 mm. thick transmitted at no wave-length more than 30 per cent. of the incident energy. A layer 2 mm. thick would, therefore, be totally opaque for wave-lengths greater than $2{\cdot}3\,\mu$. This is an

* 'Roy. Soc. Proc.,' vol. 35, p. 328.

† 'Wied. Ann.,' vol. 52, p. 216 (1894).

essential fact from our point of view, for it means that the radiation reaching the lens must be of shorter wave-length than 2·3 μ, and is therefore able to pass readily through ordinary glass.

We next turned our attention to the second part of our enquiry, namely, to what extent do the various structures of the eye receive and absorb the infra-red radiations. We attacked the question in two ways, partly by direct experiment, and partly by calculation from the measured absorption of a standard thickness of water. The results obtained by the two methods agreed with one another.

Table III.—Absorption by Water in Percentage of Incident Heat Energy.

Å.U.	Thickness.	Readings.				Mean.	Log of reciprocal.
	mm.	p.c.	p.c.	p.c.	p.c.		
7,000	30·6	102·5	97	98	101	*99*	0·0044
7,500	—	95	93	96	94·5	*94·5*	0·0246
8,000	—	91·2	89·8	95	92	*92*	0·0362
8,500	—	90	92·1	91·3	90·7	*91*	0·0410
9,000	—	88	86·9	86·6	87·1	*87*	0·0605
9,500	10·5	72·3	72·6	73	71·8	*72·4*	0·1403
9,750	—	67·5	67	67·3	67·4	*67·3*	0·1720
10,000	—	74	74	73·1	74·2	*73·8*	0·1319
10,500	—	90·2	91·4	91·5	90·3	*90·9*	0·0414
11,000	—	85·5	85·3	85·4	84·5	*85·2*	0·0696
11,500	—	42·2	43	42·6	43·5	*42·8*	0·3686
12,000	—	30·7	31·3	30·3	30·4	*30·7*	0·5129
12,500	—	33·2	33·9	33·3	33·6	*33·5*	0·4750
12,750	—	33·5	33·6	34·3	33·1	*33·6*	0·4737
13,000	—	27·6	26·3	26·4	26·8	*26·8*	0·5719
13,500	3	43·1	43	43·2	43·2	*43·1*	0·3655
14,000	1	24	24·4	23·6	23·9	*24*	0·6198
14,500	—	56	5·5	5·36	5·6	*5·5*	1·2596
15,000	—	13·5	13·3	13·45	13·5	*13·4*	0·8729
15,500	—	29·4	29·2	28·2	29	*29*	0·5376
16,000	3	12·2	12·4	12·45	12·15	*12·3*	0·9101
16,500	—	16·5	16·3	16·45	16·9	*16·5*	0·7825
17,000	—	14·3	13·6	13·7	14·1	*13·9*	0·8570
17,500	—	8·35	8·6	8·4	8·3	*8·4*	1·0757
18,000	1	20·5	20·9	20·4	20·65	*20·6*	0·6861
18,500	—	52	5·1	4·8	4·95	*5*	1·3010
19,000	—	—	—	2	—	*2*	1·7000
19,500	—	—	—	2·5	—	*2·5*	1·6021
20,000	—	—	—	4·5	—	*4·5*	1·3470
20,500	—	—	—	6	—	*6*	1·2218
21,000	—	—	—	7·5	—	*7·5*	1·1249
21,500	—	—	—	7	—	*7*	1·1549
22,000	—	—	—	5	—	*5*	1·3010
22,500	—	—	—	2·5	—	*2·5*	1·6021
23,000	—	—	—	0	—	*0*	—
23,500	—	—	—	0	—	*0*	—
24,000	—	—	—	0	—	*0*	—

The absorption by water at different wave-lengths is given in Table III. The values were obtained by first measuring the deflection of the galvanometer

Table IV.—Calculated Values of Heat Radiation Penetrating the Eye in the Human Subject.

Wave-length in Å.U.	I. Percentage of heat energy transmitted by cornea of that incident on cornea.	II. Percentage of heat energy reaching the anterior surface of lens of that incident on cornea.	III. Percentage of heat energy reaching the posterior surface of lens of that incident on cornea.	IV. Percentage of heat energy reaching retina of that incident on cornea.
7,000	97·5	95	95	94·3
7,500	97·5	95	94·6	91·3
8,000	97·5	94·5	93·6	89·6
8,500	97·5	94·2	93	89
9,000	97·2	93·6	91·9	86·1
9,500	94·4	85·4	76·2	48
9,750	93·6	83·1	72·5	41·2
10,000	94·5	85·8	77·2	50·3
10,500	96·6	92	89	77·6
11,000	95·9	90	85·1	67·7
11,500	89·4	71·5	53·2	15·9
12,000	86·4	63·7	42·2	7·9
12,500	87·0	65·7	44·9	9·5
12,750	87·3	65·6	44·8	10·6
13,000	85·4	61	37·7	6·55
13,500	75·0	36·4	13·4	0·24
14,000	23·5	0·72	—	—
14,500	5·5	0·00	—	—
15,000	12·9	1·1	—	—
15,500	28·0	1·37	—	—
16,000	48·2	8·7	0·73	—
16,500	53·3	12·2	1·44	—
17,000	51·4	10	0·95	—
17,500	43·5	5·6	0·30	—
18,000	20·3	0·42	—	—
18,500	4·9	—	—	—
19,000	2	—	—	—
19,500	2·5	—	—	—
20,000	4·4	—	—	—
20,500	6	—	—	—
21,000	7·6	—	—	—
21,500	7·1	—	—	—
22,000	5	—	—	—
22,500	2·5	—	—	—
23,000	0	—	—	—

This Table is shown plotted in fig. 6.

with the trough filled with water, and then measuring at the same wave-length the deflection without the water. The percentage absorption of the water only was then obtained by stating the first measurement in percentage of the second. In measuring the deflection without the water the empty trough was not used, as it would introduce an extra pair of glass–air surfaces instead of two glass–water ones. We used instead two glass plates of the same thickness as the sides of the trough clamped together with a thin film

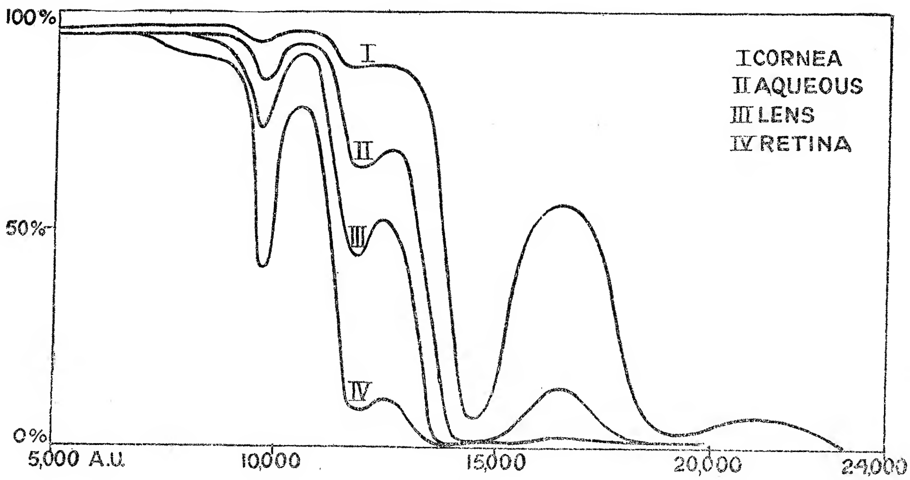

Fig. 6.

of water between. In this way the loss of light at the surfaces of the trough was allowed for. Water of several thicknesses was measured in order to give suitable values from which to calculate the absorption by thin or thick layers of eye media. From these measurements we then calculated the absorption by the different structures of the eye, using the values given in Table V for their thickness and the percentage of water contained in them.

Table V.

Structure.	Thickness.	Refractive index.	Water.	Equivalent thickness of water.
			per cent.	
Cornea	1·15	1·377	90	1·04
Aqueous humour	2·4	1·335	99	2·38
Lens centre	—	—	84	—
Lens cortex	4·05	1·39	92	3·55
Vitreous humour	15	1·34	96	14·4

(The values in the last column were calculated by multiplying the thickness of the structure by the percentage of water contained by it.)

Table VI.—Calculated Values of Heat absorbed by Cornea, Lens, and Iris.

Wave-length in Å.U.	I. Percentage of heat energy absorbed by cornea of that incident on cornea.	II. Percentage of heat energy absorbed by iris of that incident in cornea.	III. Percentage of heat energy transmitted by lens of that incident on lens.	III. Percentage of heat energy absorbed by lens of that incident on cornea.
7,000	—	95	100	—
7,500	—	95	99·4	0·4
8,000	—	94·5	99·1	0·9
8,500	—	94·2	98·8	1·2
9,000	0·3	93·6	98·2	1·7
9,500	3·1	85·4	89·3	9·2
9,750	3·9	83·1	87·1	10·6
10,000	3	85·8	90·0	8·6
10,500	0·9	92	96·7	0·3
11,000	1·6	90	94·6	4·9
11,500	8·1	71·5	74·3	18·3
12,000	11·1	63·7	66·2	21·5
12,500	10·5	65·7	68·4	20·8
12,750	10·2	65·6	68·3	20·8
13,000	12·1	61	63·1	24
13,500	22·5	36·4	36·9	23
14,000	74	72	0·63	0·72
14,500	92	—	—	—
15,000	84·6	1·1	0·08	1·1
15,500	69·5	1·37	1·23	1·37
16,000	49·3	8·7	8·4	8
16,500	44·2	12·2	11·8	10·8
17,000	47·2	10	9·53	9
17,500	55·2	5·6	5·37	5·3
18,000	77·4	0·42	0·36	0·42
18,500	92·5	—	—	—
19,000	95·5	—	—	—
19,500	95	—	—	—
20,000	93	—	—	—

This Table is shown plotted in fig. 7.

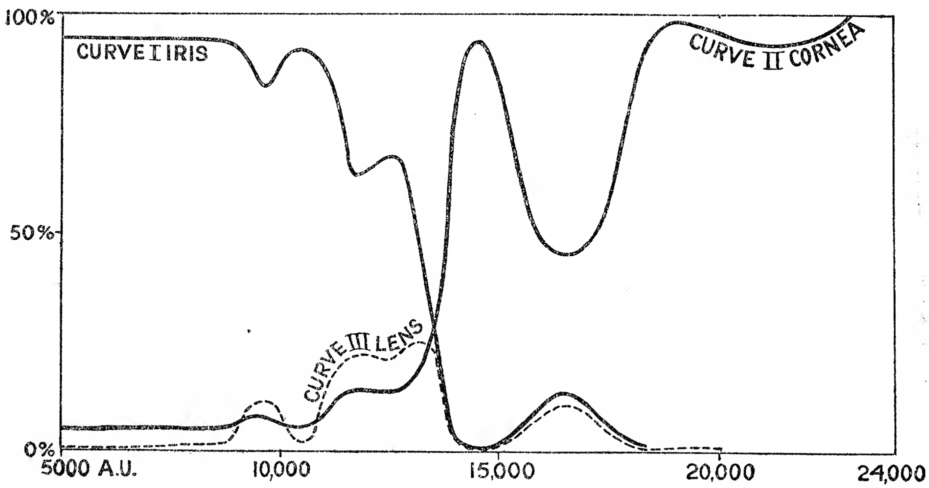

Fig. 7.

Now besides absorption by the eye structures a certain small amount is lost by reflection at the different surfaces and by scattering, since the eye media are not entirely homogeneous. Heat lost by reflection is greatest at the anterior corneal surface, being about 2·5 per cent. At the other surfaces about 0·5 per cent. is lost. The probable total loss by reflection and scattering we have assumed to be 5 per cent. The values in the above Tables are shown plotted in figs. 6 and 7. Examination of these Tables shows that the heat radiation from λ 11,000 to λ 7000 passes into the eye almost unchecked and a great deal of it reaches the retina. This entirely confirms the results obtained by Vogt mentioned above.

Now, we found the iris of the ox totally obstructed heat radiation of every wave-length which fell upon it. It therefore absorbs the same percentage radiation as that which reaches the anterior surface of the lens; that is roughly 75 per cent. of the heat radiation between λ 13,000 and the visible spectrum. The lens, on the other hand, absorbs of the radiation allowed to reach it through the aperture in the iris only a very small percentage of the incident light energy, approximately 12 per cent. Thus, in the case of the ox and the radiation from a naked Nernst filament, four times the amount of energy is absorbed per unit area by the iris as is absorbed by the lens. The difference is, of course, still greater when unit volume is considered. Now, although an actual coagulation of the lens proteins brought about in the course of time by this small amount of heat radiation is not impossible, when the conclusions of Chick and Martin* with regard to the physical chemistry of coagulation are considered, yet we think it more likely that the change is due to some interference with the nutrition of the lens caused in some way by the enormous heat-absorbing power of the iris affecting the secretion of the aqueous humour by the ciliary body, as Parsons suggests.† It would be premature to speculate what the connection between the heat stimulus on the iris and the secretion of aqueous may be, but several interesting points may, perhaps, be briefly mentioned.

Firstly, the heat radiation is probably absorbed but slightly by the pigment in the substance of the iris, by far the greater amount of energy passing through and being finally absorbed by the pigment on its posterior surface. In the case of blue-eyed individuals the pigment in the stroma of the iris is absent and the posterior pigmentary layer is alone effective in absorbing radiant energy. This means that not only does the absorbent layer come in intimate contact with the posterior chamber of the eye, but also with the

* 'Journ. Physiol.,' vol. 40, p. 404 (1910).

† 'Affections of the Eye produced by Undue Exposure to Light,' Report to Section of Ophthalmology, British Medical Congress.

processes of the ciliary body themselves. A rise of temperature of the pigment layer due to the absorption of heat must necessarily cause at the same time a rise of temperature by conduction to surrounding structures, in this the glandular elements of the ciliary body take part.

Secondly, the very intimate relationship that exists between the arterial supplies of the iris and ciliary processes may be mentioned, both coming off as branches from the circulus arteriosus major. It is possible that the lymphatic drainage is no less intimate, it is also conceivable that the vaso-motor nerves to these arteries also send glandulo-motor nerves to the ciliary processes; on these points, however, we have only the evidence of analogy with other secretory organs.

There are several remarkable features in the occurrence of glassmakers' cataract; the very long period taken for the condition to develop does not at all suggest any pathological change of an inflammatory nature, neither has any obvious change in any other structure of the eye apart from the lens been described. Thus the pupil is normal in size and reaction to light, which would not be the case if it had been the seat of any chronic inflammatory change. It would seem to us more likely therefore that the change in nutrition of the lens is one brought about by some physiological alteration in the secretory mechanism of the aqueous rather than to a pathological change. We have only to postulate a secretion of aqueous when heat falls on the iris to obtain what appears to be a plausible hypothesis of the formation of the cataract. Normally aqueous is secreted in small amounts all the time; when heat falls on the iris a larger secretion occurs, which is followed when the stimulus stops by a period of rest. This stimulus, falling regularly for long periods, in time causes the secretory mechanism to be more and more dependent on the external stimulus. The secretion becomes periodic in character and, instead of the lens receiving nourishment all the time, it only receives it at intervals, with the result that the least well nourished part of the eye suffers and cataract develops.

Whether or not the heat absorbed by the iris stimulates the secretion of aqueous humour, and how it stimulates it, whether by rise of temperature, vaso-dilatation or actual reflex stimulation, experiment alone can show. Our object in mentioning the matter here is that it seems to us to offer a feasible line of attack for future investigation.

Protection of the Eye from Harmful Radiation by Crookes Glasses.

In order to protect the eye from damage by the radiation from luminous bodies, it is necessary to remove as completely as possible the ultra-violet and infra-red rays, for these, while taking no part in the vision of external objects,

do at the same time cause injury to the eye structures that absorb them. The visual rays when present in excessive amount or when coming from a source in a position to form sharply focussed images of filaments, etc., on the retina (eclipse blindness) also do harm, and should therefore be reduced in intensity by suitable neutral grey glasses.

In the case of daylight the modifying glasses should be worn as spectacles, in the case of artificial illuminants on the other hand they should form globes, so as to limit the rays emitted to those useful for vision. For both purposes the glasses recently perfected by Sir William Crookes are ideal.

Of the many different glasses prepared by Sir William Crookes, those containing iron in the ferrous state stand prominent for their power of absorbing the infra-red rays. Three glasses of different formulæ were sent to us to be tested, and in the case of two of them we were able to contrast the specimen made by Sir William himself on a small scale with samples of a large melt by Messrs. Chance Bros. & Co., Ltd. We also obtained specimens of certain other glasses specially made for spectacles, as we thought a comparison of the properties of these with the Crookes glasses might be interesting. The glasses were examined in the following ways.

The infra-red radiation was estimated by a simple arrangement of filament, condenser, and thermopile, the latter being enclosed in a box and carefully insulated with wool from radiation from surrounding objects. A comparison of the deflection of the galvanometer with and without the glass gave the summation of the effects of all the radiation emitted by the Nernst lamp. We then limited the radiation to the infra-red region by a gelatine absorption filter which absorbed everything shorter than λ 6700. (The construction and properties of this filter will be described later.) Finally we added a trough which contained 7·5 mm. thicknesses of water.

The transparency to visual rays was measured in a simple comparison photometer, the white equivalent being obtained by comparing the absorption of the glass with that of a standardised graduated neutral gelatin wedge. Colour filters were then placed over the eyepiece which limited the spectrum to the red, green or blue as required.

The ultra-violet transmitted by the glasses was estimated by a photographic method. In front of a fast non-colour-sensitive photographic plate was placed a gelatin filter which removed the visual radiation likely to affect the plate, while it allowed the ultra-violet to pass, the dyes used in preparing the filter being methyl violet and paranitrosodimethyl aniline. Over this were placed the specimens of glass to be tested, and along the edge of the plate was placed a graduated step-wedge. Light was then allowed to fall perpendicularly on the plate holder and after exposure the plate was developed in the usual

Table VII.—Comparative Values for Percentage of Visual Infra-red and Ultra-violet Rays transmitted by Crookes Glasses and by Certain Other Glasses.

	Thickness, in mm.	Heat passed by water (10 mm. thickness).	Heat from λ700 to end of spectrum.	Red λ575–λ725.	Green λ510–λ575.	Blue λ440–λ510.	Total visual.	Ultra-violet.	Ultra-violet absorption extends to λ =
				Window Glass.					
Yellow	2·2	80	71	45	21	2	35	4	500
Blue	2·13	55	25	0·5	1	18	5	—	440
Signal green	1·55	5	22	1·5	24	40	15	4	—
				Spectacle Glass.					
Green	1·8	13	25	13	51	40	30	2·5	430
Amber	1·6	85	65	65	41	14	40	5	480
Chloroph	1·4	80	75	32	27	10	25	3	490
Furizel	1·9	65	60	26	24	7	20	2	500
Orange yellow	1·8	55	45	57	42	18	45	3	480
Euphos	1·75	95	78	53	77	40	60	5	460
				Crookes Glass.					
256	1·8	2·5	*21·5*	52	74	75	*62*	40	*354*
56	2·12	2·3	*17·5*	56	74	76	*63*	50	*340*
246	2·0	0	*2*	13	22	23	*20*	2·5	*380*
31 and 32	2·6	0	2·5	19	39	25	*29*	4	*362*
217	1·83	0	*4*	42	55	62	*44*	10	*347*

All values are per cent. intensity of transmitted light. Last column values are approximate only. Italic figures in last series are Crookes' values.

Table VIII.—Various Glasses. Infra-red only.

Wave-length ...	70.	80.	90.	100.	110.	120.	130.	140.	150.	160.	170.	180.	190.	200.
Yellow	52	55	54	56	56	57	58·5	59	61	61	60·5	60·5	61	60
Signal green	—	—	—	—	—	—	—	4	11	18·5	25	33	37	43
Blue	25	62	61	52	36	22	20	19·2	17	19·5	20	19	31	34
Green	—	1·5	3	8·5	17	27	38	47	56	62	66	70	75	65
Amber	76	71	73	78	80	82	84	86	86	87	90	88	88	88
Chloroph	59	68	70	76	77	82	83	85	84·5	85	81	79	78	78
Furizel	47	61	64	66	66	73	76	80	79·5	77	77	77	77·5	70
Orange yellow	59	54	53	54	61	65	67	73	76	77	77·5	76	76	67·5
Euphos	62	72	81	88	88	91	90	92	91·5	91	93	91	90	90
256	33	12	4	3	1·8	2·5	2·7	4·2	6·3	9·4	13	13	12·5	13
56	24	10	3	3	2·2	1·8	2·7	4·7	7	10·4	13·5	14·5	15	15
246	5	2	2	1·5	1	—	—	—	0·5	0·5	0·6	0·7	—	—
31	8	3·5	—	—	—	—	—	—	1	0·5	0·85	1·1	0·9	2·1
217	14	2	—	—	—	—	0·3	0·7	1·4	2·5	3·2	4	4·4	4·3

way. The depth of the silver deposit was then measured in the areas corresponding to the glasses. The densities corresponding to the step-wedge were measured in a similar manner, and the results plotted against the known values of the wedge absorption. The densities in the areas corresponding to the glasses were then referred to this curve, and the absorption stated in percentage of the incident radiation.

The infra-red radiation at different wave-lengths was obtained by the infra-red spectrophotometer used in testing the absorptions of the eye.

The results obtained by us are given in Tables VII and VIII, pp. 73–74. Comparison of the values for the different glasses shows the great infra-red absorbing power of the Crookes glasses compared with the other glasses tested. The transparency of these glasses is very considerable, while their ultra-violet absorbing power is not so great as some of the more heavily coloured orange and green glasses previously manufactured.

The formulæ of the Crookes glasses were approximately as follows:—

No. 256.*

	Per cent.
Soda flux	81
Cerium nitrate	11
Ferrous oxalate	5·4
Tartar	2
Charcoal	0·5

No. 246.†

Soda flux	90
Ferrous oxalate	10
Tartar	—
Charcoal	—

No. 217.†

Soda flux	96·8
Ferrosoferric oxide	2·85
Carbon	0·35

To facilitate comparison between the optical properties of glasses made to the above formulæ we have calculated from the values in Table VII the thickness of plate required to reduce the visual rays by 50 per cent. From

* Sir W. Crookes kindly sent us the formula of this glass for publication.

† 'Phil. Trans.,' A, vol. 214, p. 20 (1914).

this we then estimated the percentage absorption of infra-red and ultra-violet rays by such a plate.

No. of glass.	Thickness.	Visual.	Infra-red.	Ultra-violet.
	mm.			
256	2·61	50	10·7	26·4
246	0·86	50	18·6	20·4
217	1·55	50	6·61	14·3

Glass 217 would, therefore, appear to be the most efficient in removing rays likely to injure the eye. Its colour is a pale green, very pleasant to use, and the eye quickly becomes accustomed to the slight coloration. Colour matches appear to be but little affected by it.

Soil Protozoa and Soil Bacteria.

By Edward John Russell (Rothamsted Experimental Station).

(Communicated by Dr. Horace T. Brown, F.R.S. Received May 3, 1915.)

In a paper recently published by Mr. Goodey* it is definitely asserted that ciliates, amœbæ and flagellates cannot function as a factor limiting the numbers of bacteria in soils. It does not appear to me that this conclusion is justified by the experimental data given in this paper, and in view of the importance of the subject it seems desirable to bring together the main facts so far ascertained and to summarise the present position of the problem.

Soil consists of irregular mineral particles of sizes varying from about 1 mm. diameter downwards, together with a smaller proportion of organic substances of varying degrees of complexity, nutrient and other salts, and the oxides of iron, aluminium, and silicon in a form easily soluble in acids or alkalis. The action of the natural processes tends on the whole to effect intermingling of these constituents, at any rate throughout the top 6 inches.

In its physical properties soil behaves like a colloid; it possesses strong powers of absorption, and the phenomena are exactly parallel with those shown by other colloids; it influences the evaporation of water so that the curves become wholly different from those obtained from a water surface or from sand. The evidence all shows that the colloidal constituents are not segregated but are distributed over the surface of the mineral particles. Thus the soil may be looked upon as a mineral framework coated with a

* 'Roy. Soc. Proc.,' B, vol. 88, pp. 437–456.